OBSERVING COLD, CLUMPY ACCRETION ONTO SUPERMASSIVE BLACK HOLES

TOM ROSE

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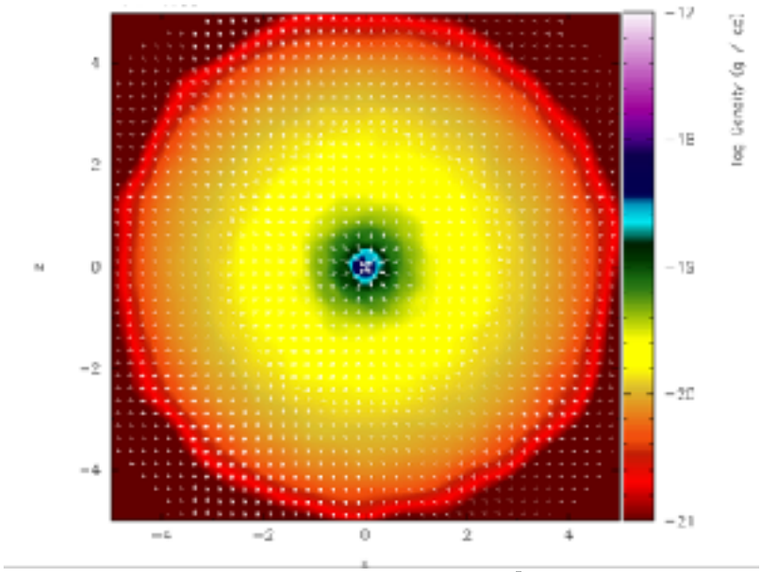
HOW DO SMBHs ACCRETE THEIR FUEL?

- The evolution of a galaxy is influenced by the accretion of gas onto its central SMBH
- A myriad of theoretical models exists for SMBH accretion, e.g.:

Bondi accretion:



P. Barai et al.

L. Calçada/ESO

- Outflows are observed considerably more than inflows: observational evidence to support accretion models is lacking

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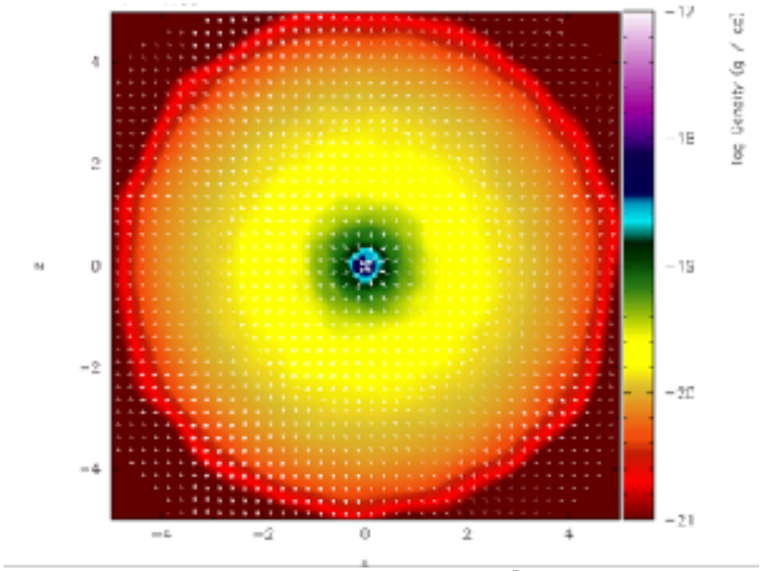

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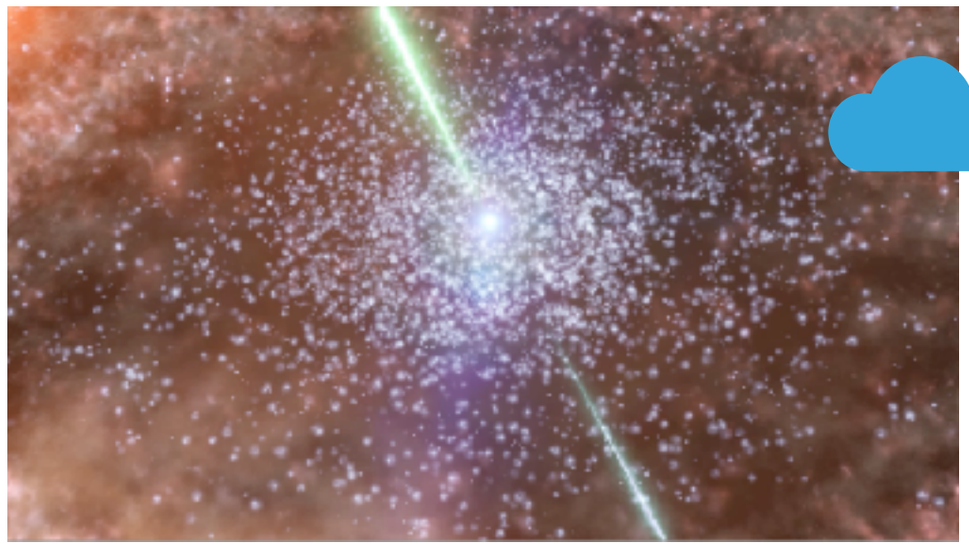
Chaotic Cold Accretion:



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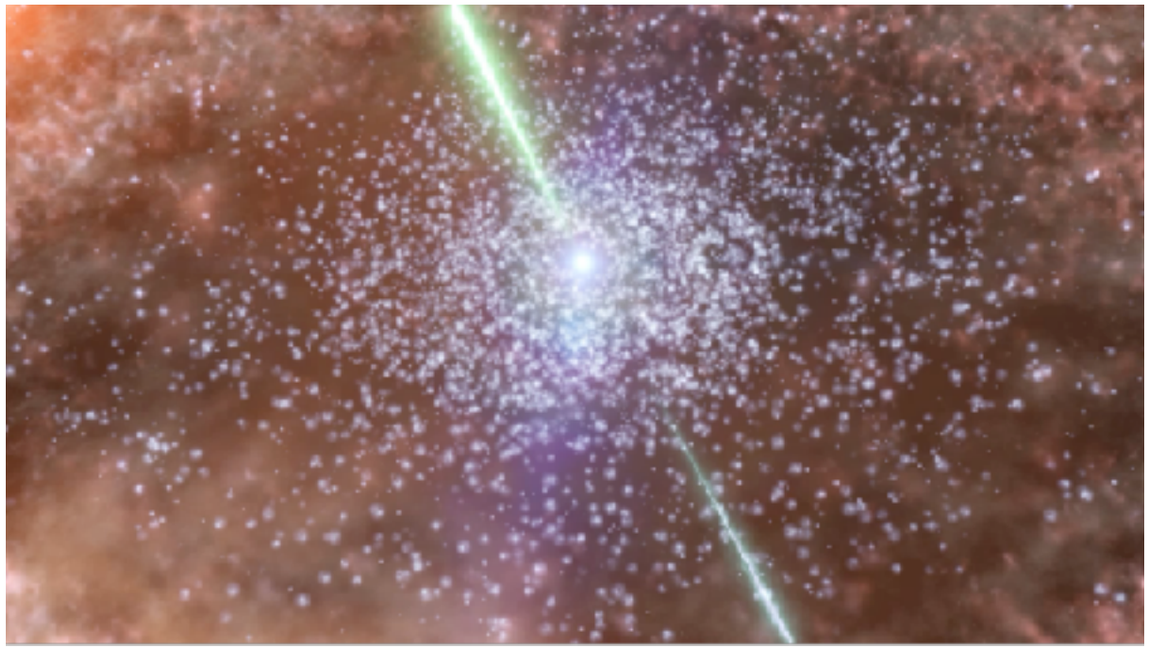
STUDYING SMBH ACCRETION USING CO ABSORPTION

- The AGN of BCGs provide an extremely bright backlight
- Cold molecular clouds along the line-of-sight can be detected from CO absorption of the backlight continuum emission
- Inflows and outflows can be inferred from the CO lines' velocity shift



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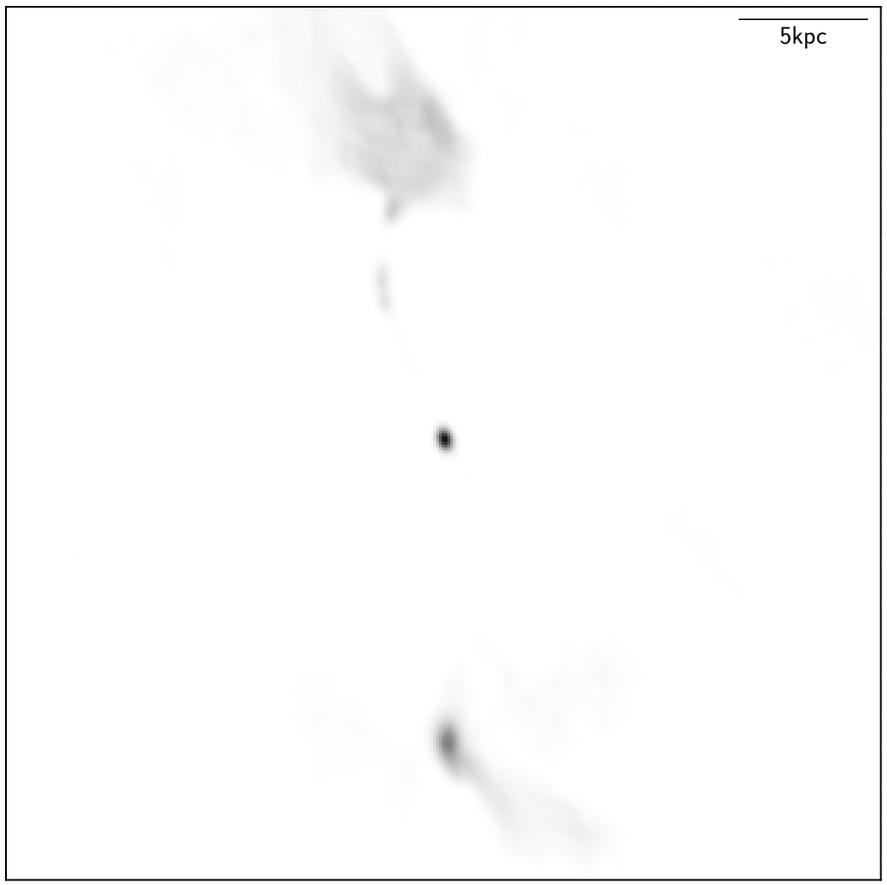

5 GHz VLA radio image

HYDRA-A BRIGHTEST CLUSTER GALAXY

z = 0.055, D = 242Mpc

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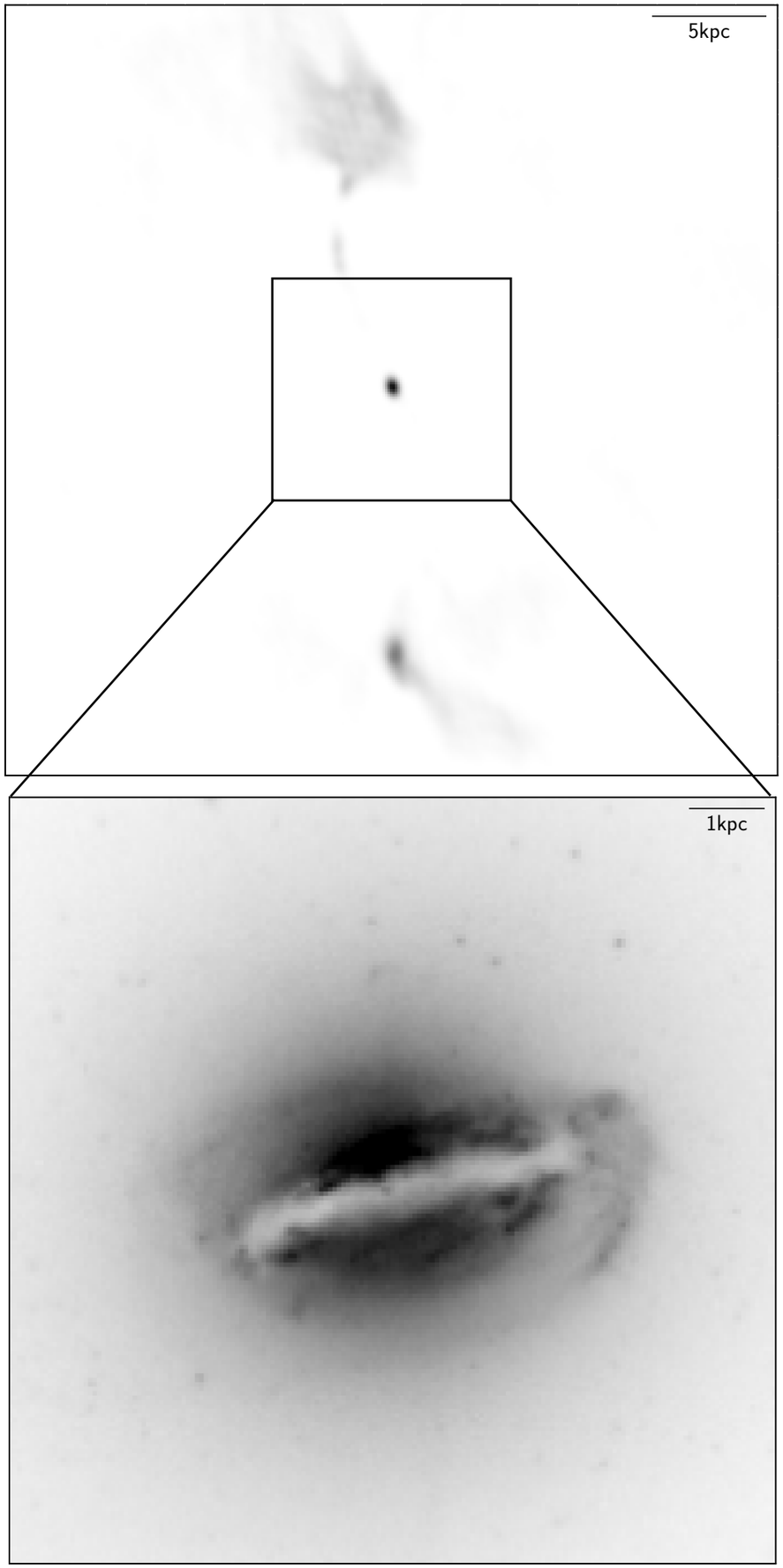

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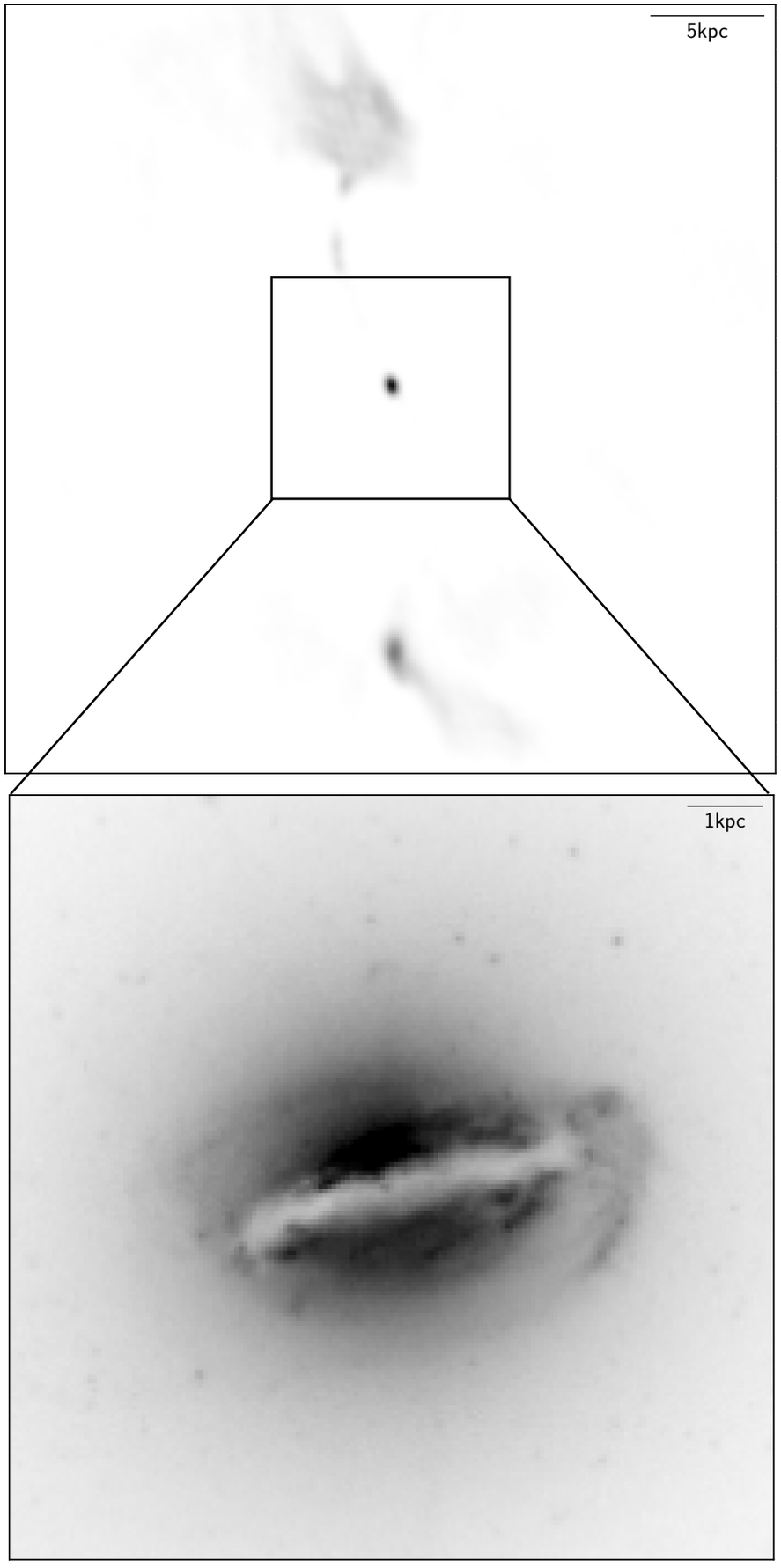

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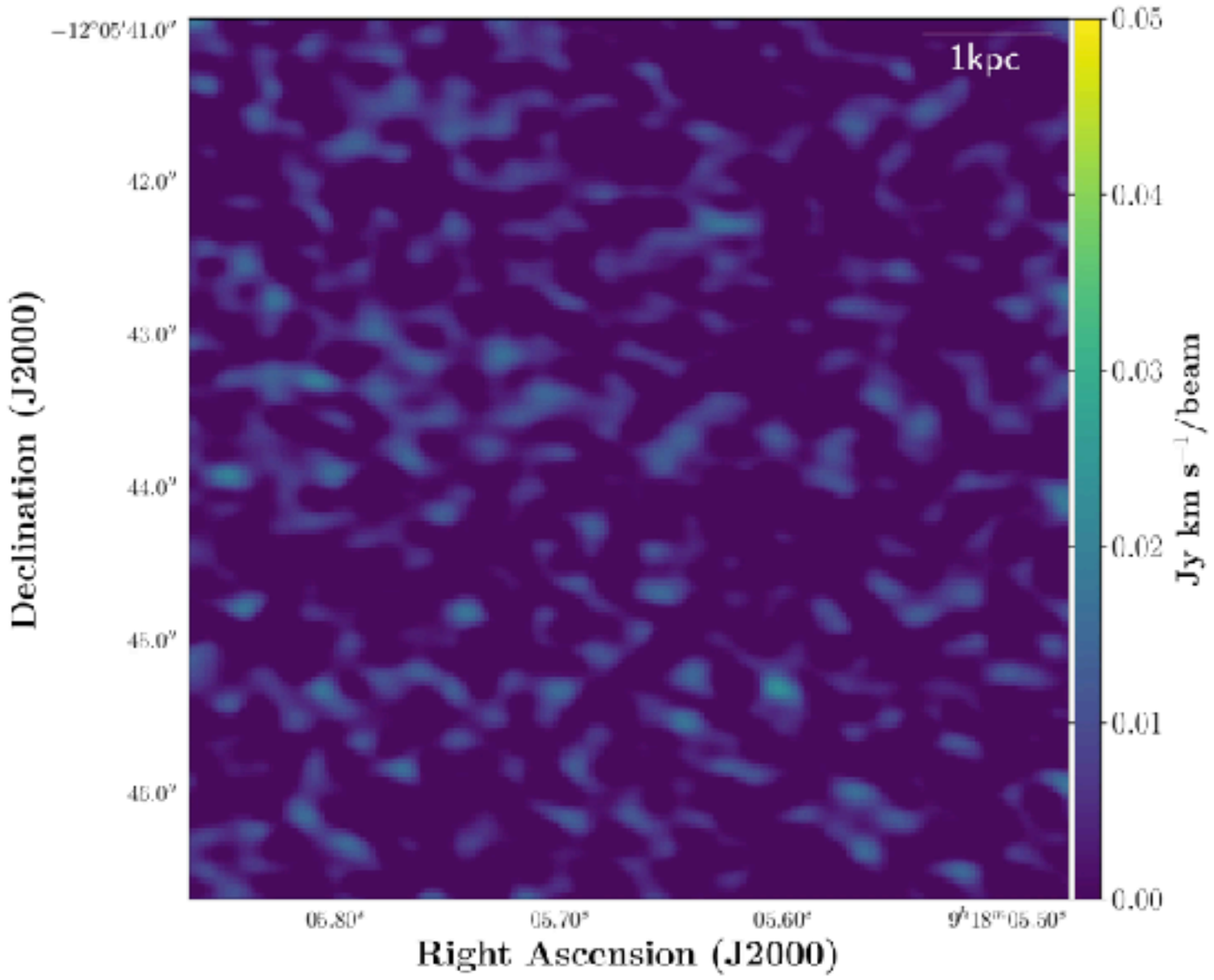
ALMA CO(2-1) observations of Hydra-A



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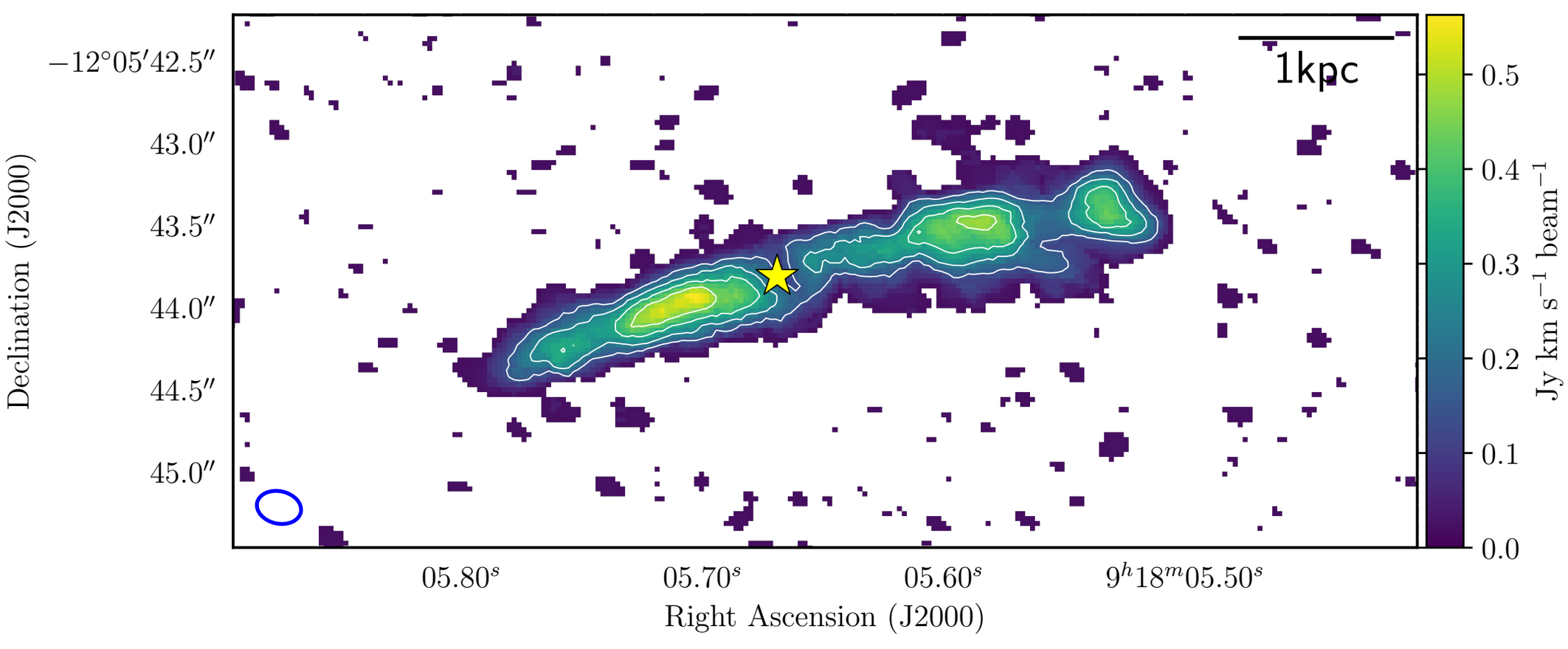

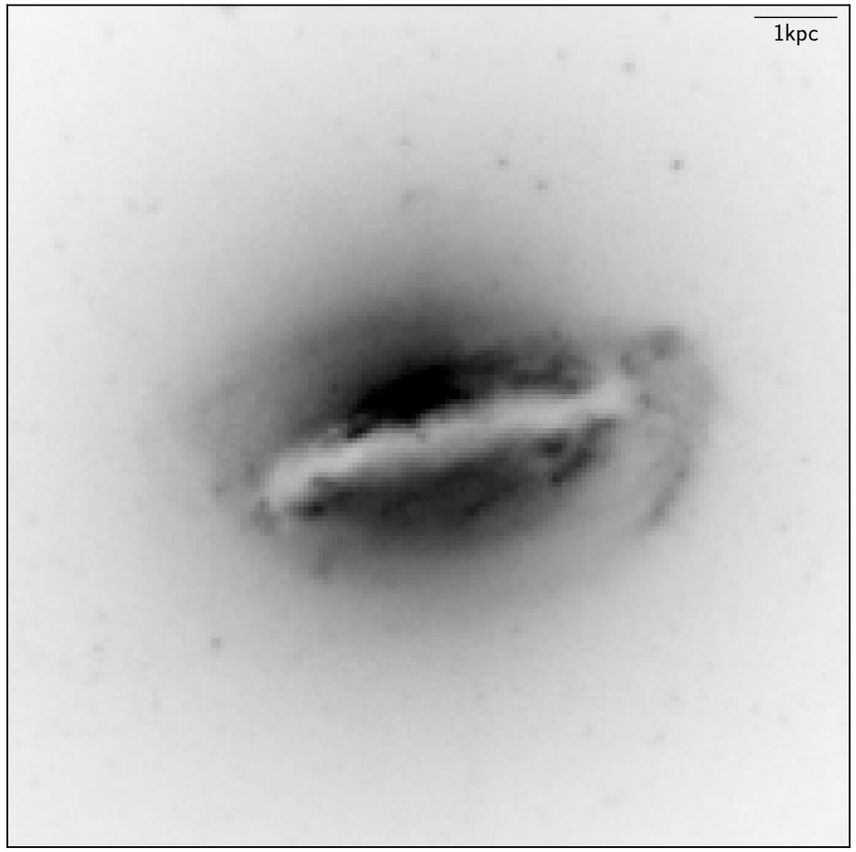

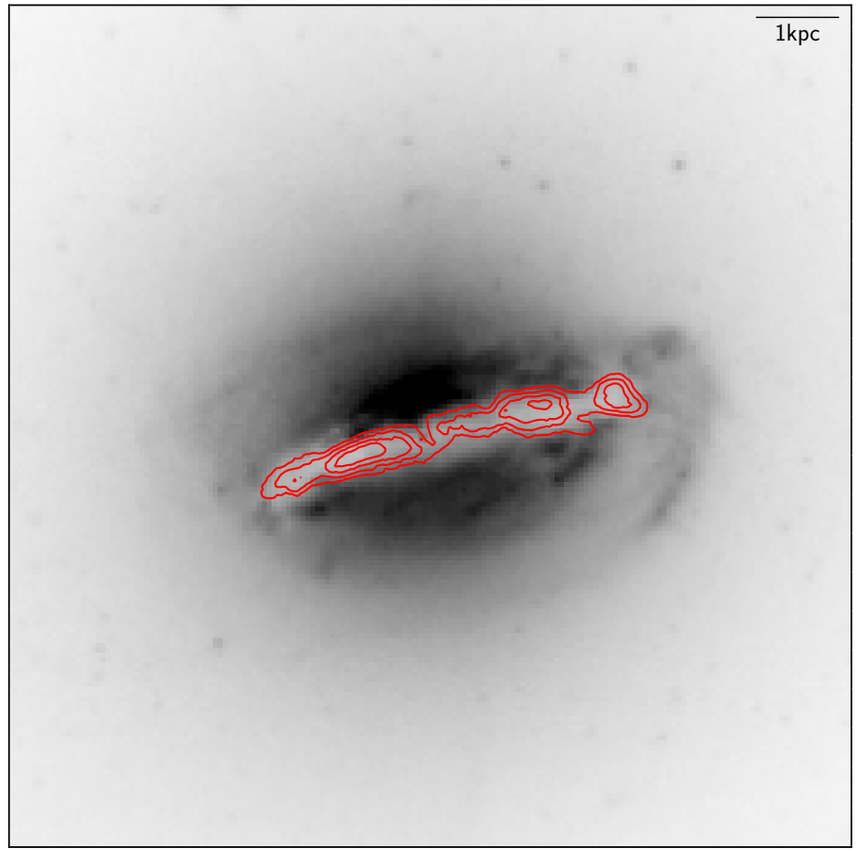

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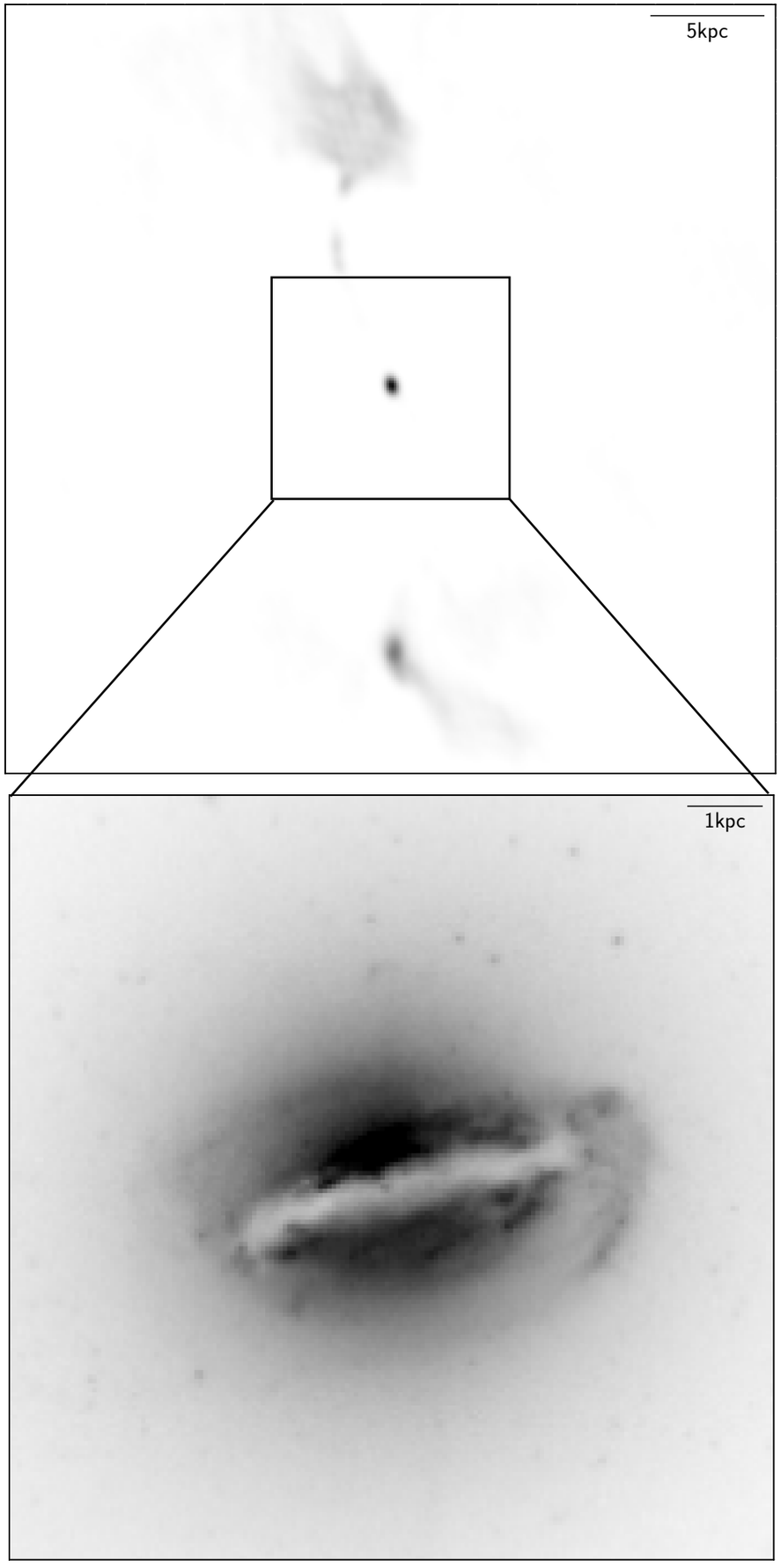

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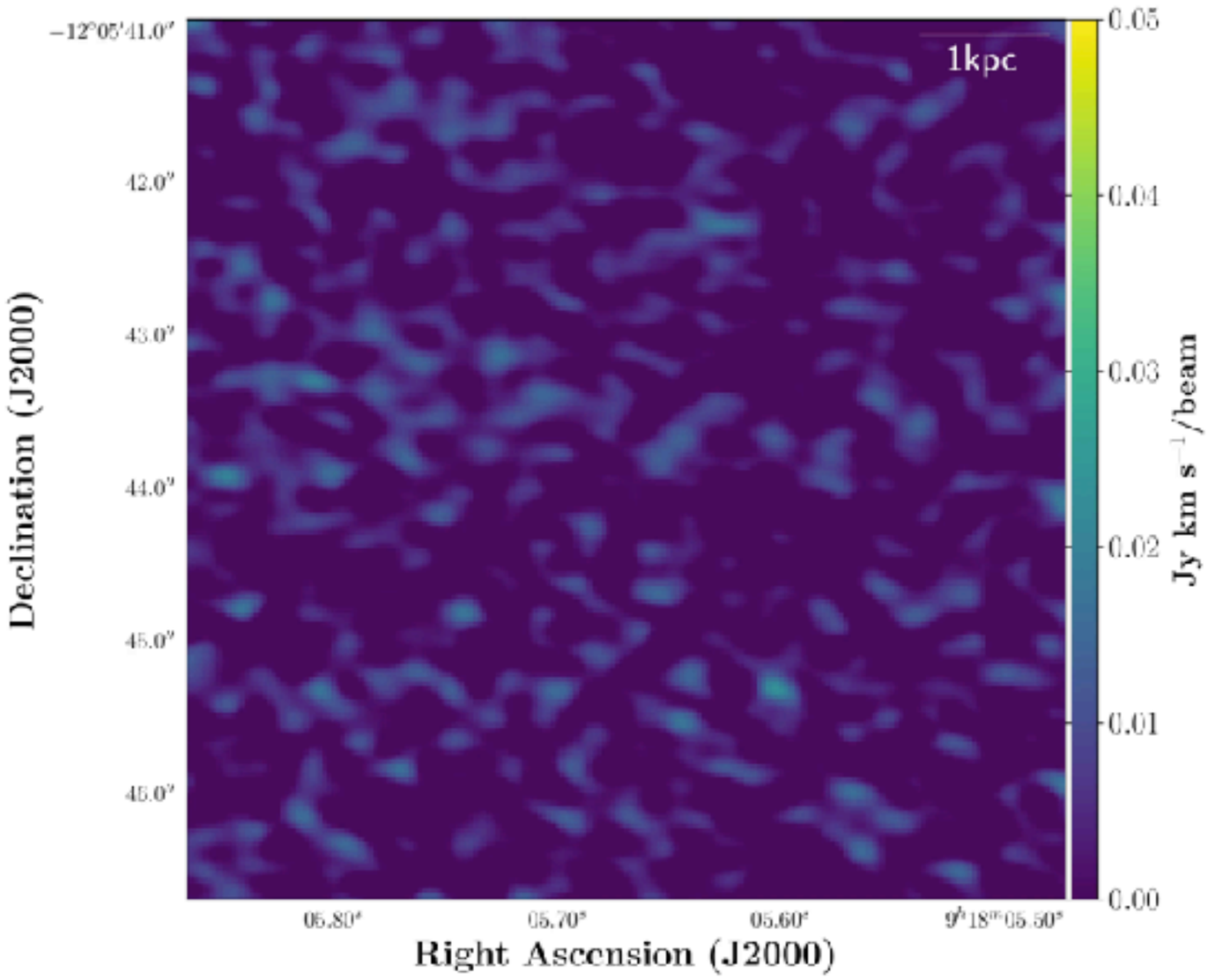

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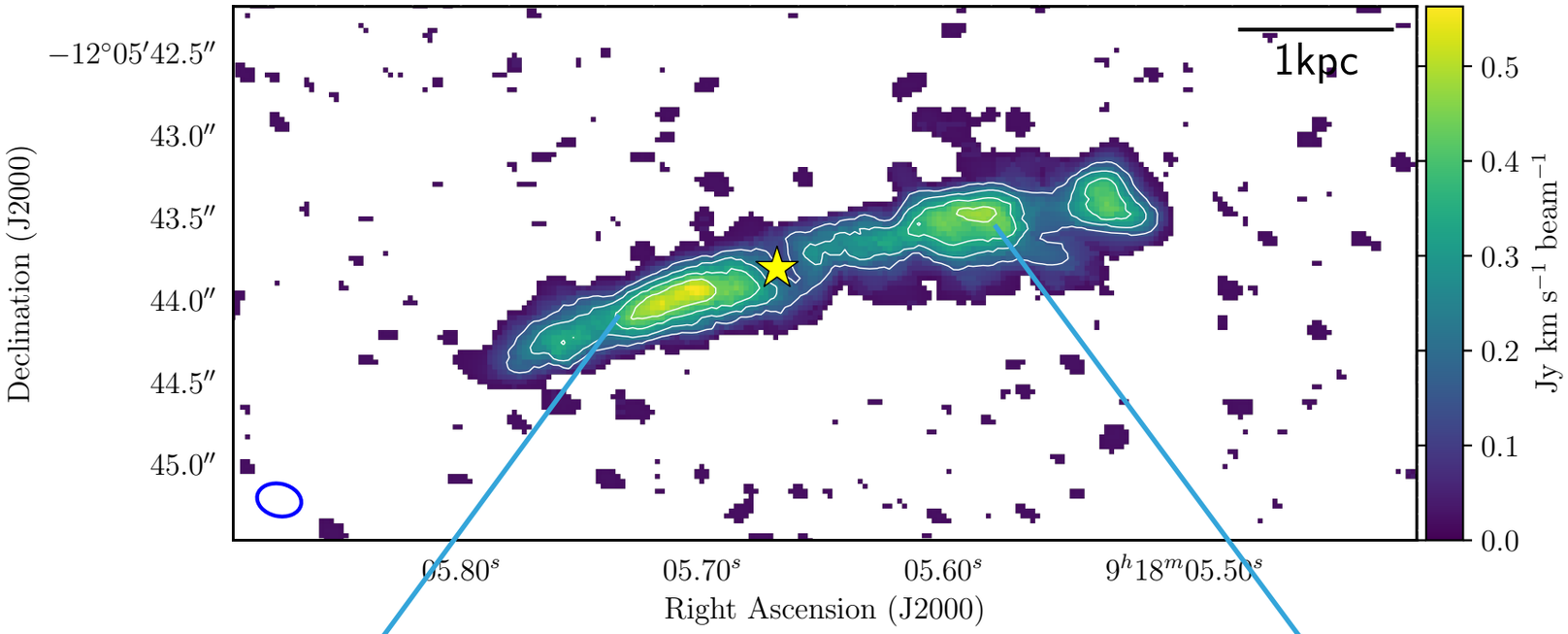

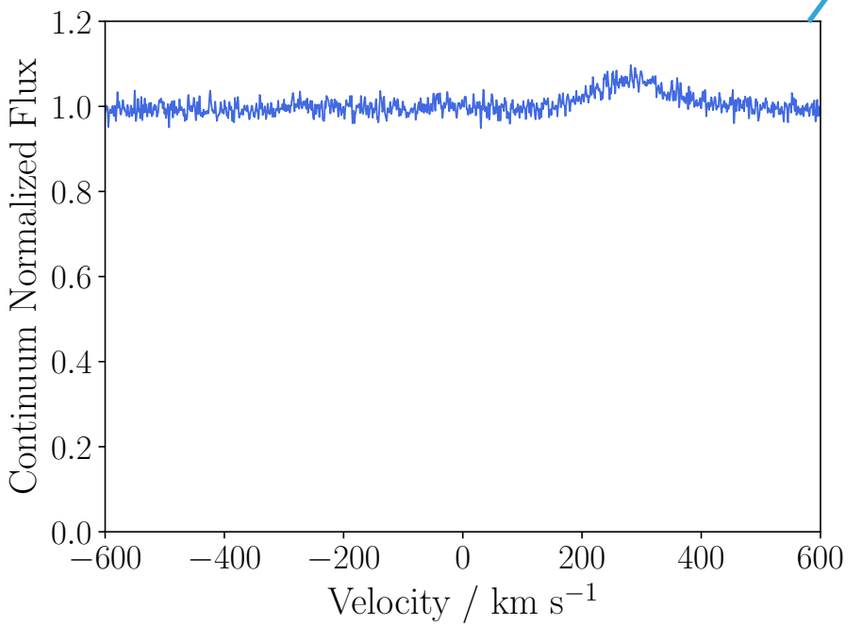

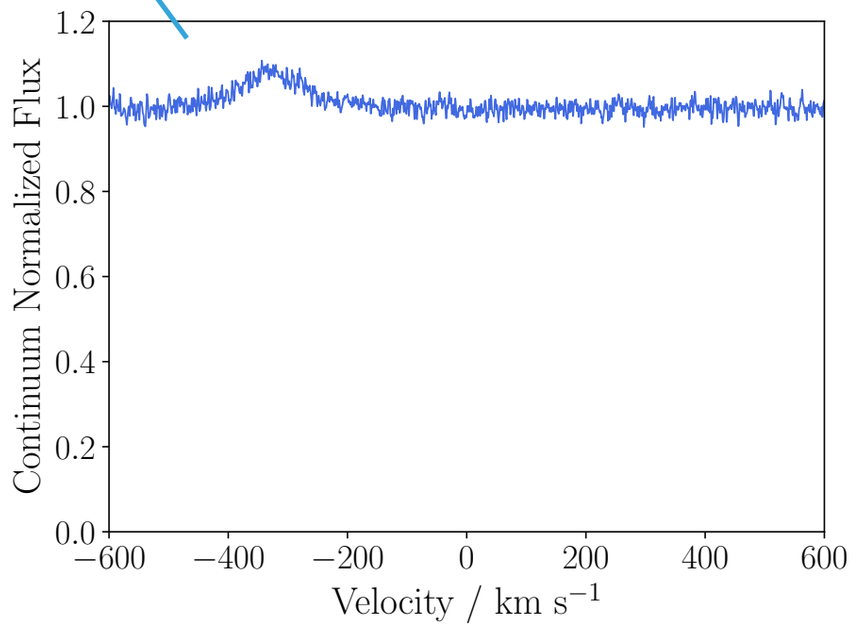

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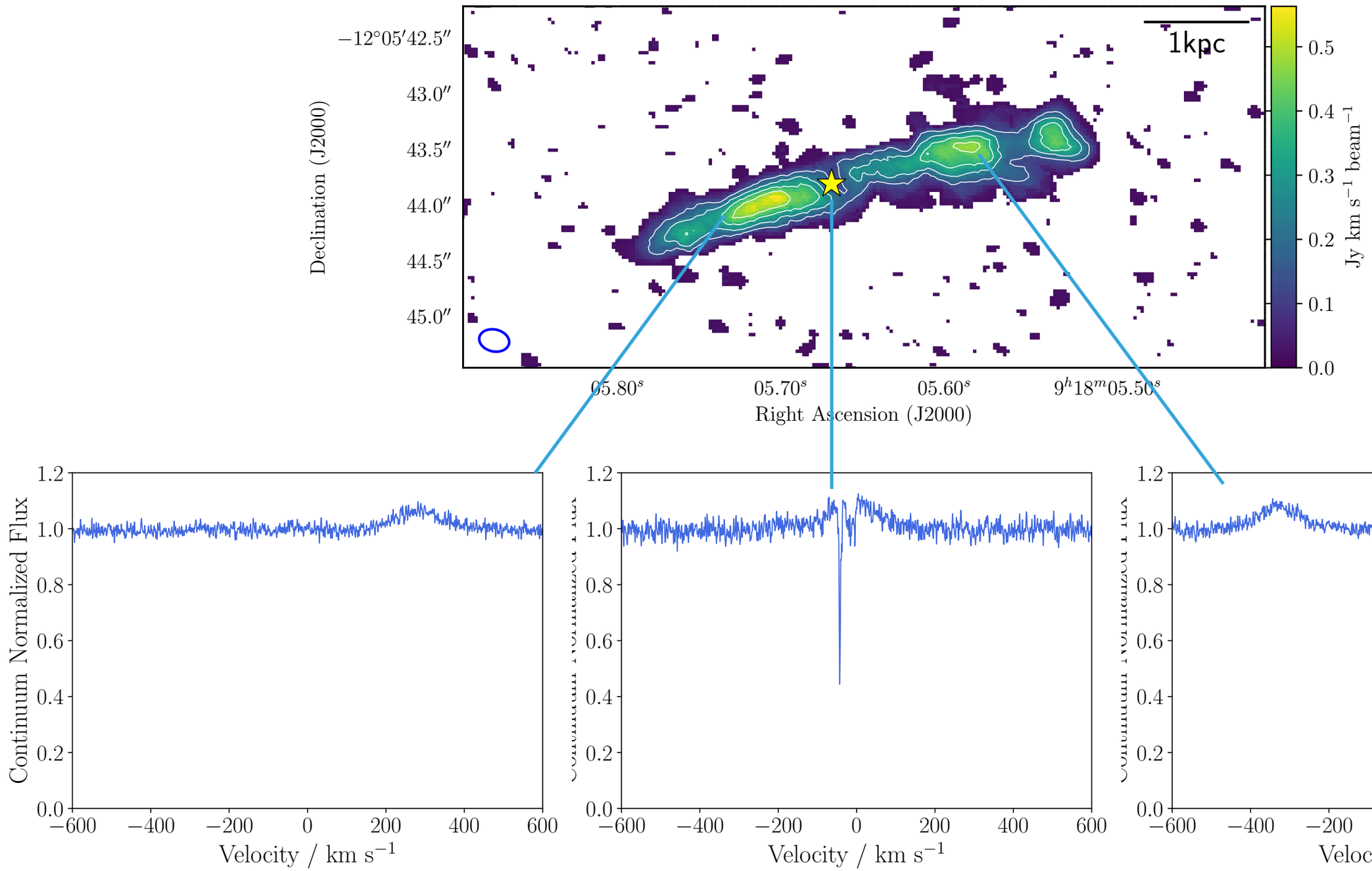

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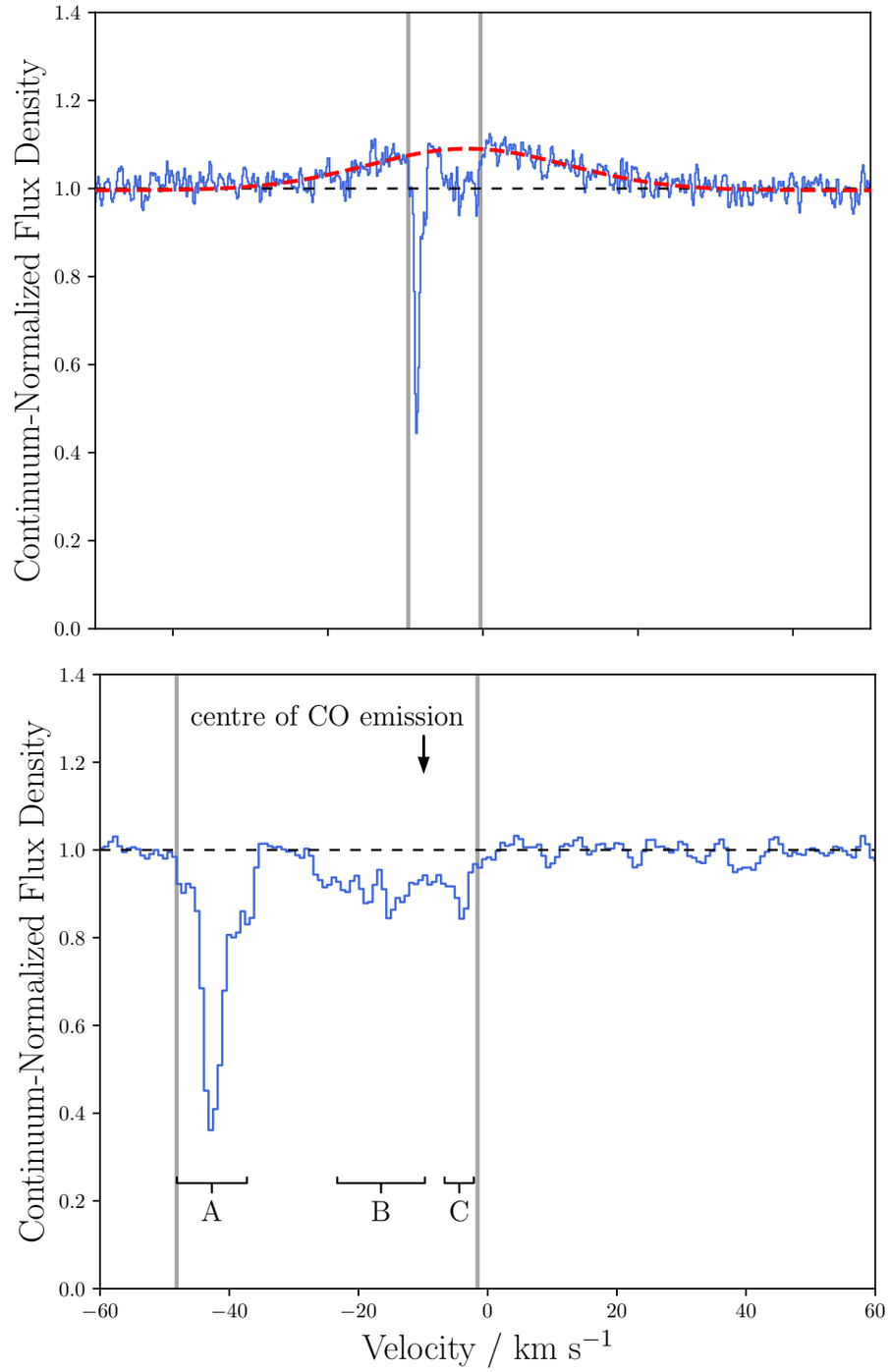
HYDRA–A's CORE SPECTRUM

- A group of distinct, absorbing regions can be seen -> cold molecular gas clouds
- These are slightly blueshifted relative to the stellar recession velocity of the galaxy
- i.e. they're moving away from the SMBH at velocities between 6 and 43 km/s
- These velocities are small, so the clouds are most likely on stable, low ellipticity orbits



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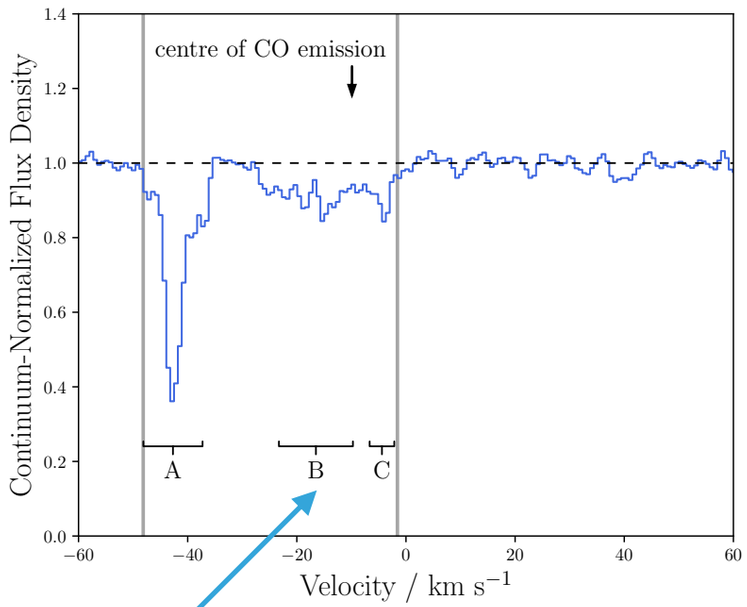
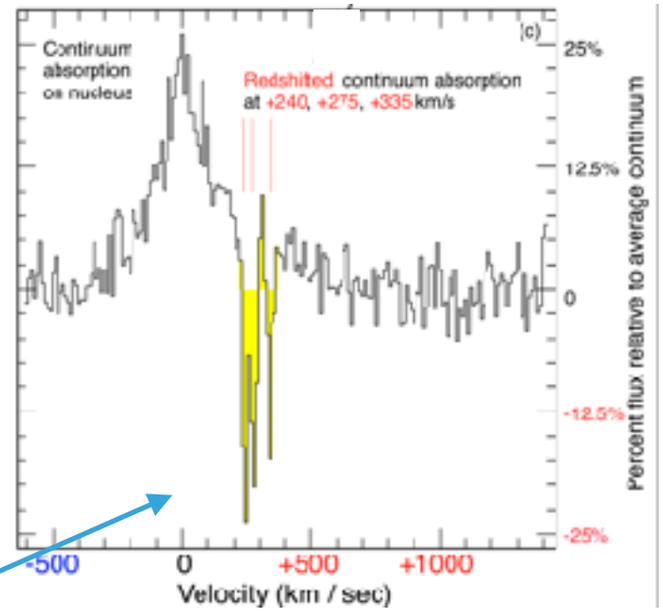
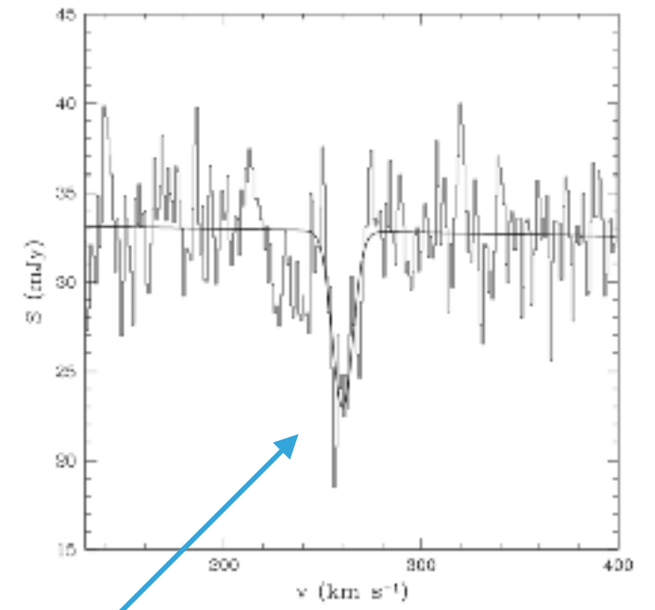
SIMILAR OBSERVATIONS







- So far there are three detections of these cold molecular gas clouds. These are in Hydra-A and A2597 (Tremblay et al. 2016), and NGC 5044 (David et al. 2014)
- You could conclude that all brightest cluster galaxies have cold molecular gas clouds along the line of sight to the SMBH
- More detections are needed to find a statistically significant value for the covering fractions of cold molecular gas clouds, their masses and the overall motions of the clouds relative to their SMBHs
- It will also be possible to compare the observed distribution of absorbing clouds to predictions from 3-D models and simulations e.g. (Gaspari et al. 2015)

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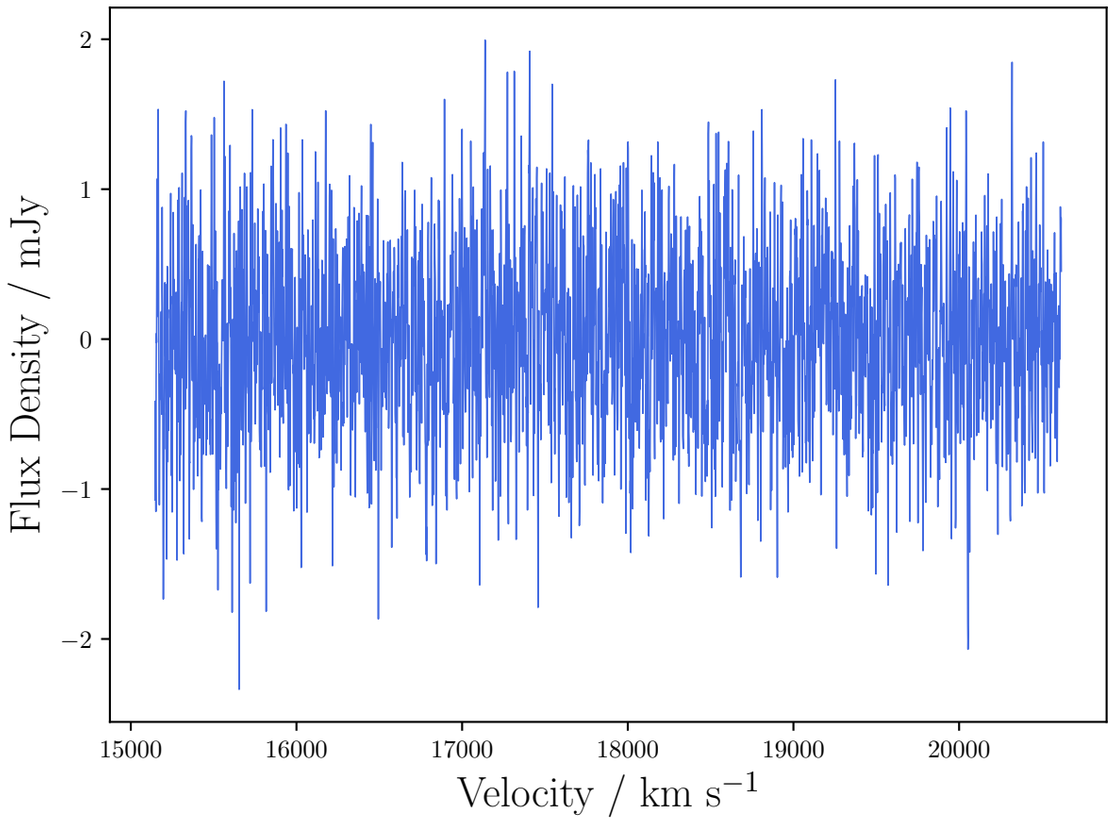
FUTURE WORK WITH ALMA

- ALMA observations have been carried out for a CO(1-0) survey of the 24 strongest mm-continuum sources known in BCGs visible from ALMA
- This will provide a statistically meaningful set of observations that will allow us to probe many lines of sight
- We will be able to determine the overall properties of absorbing molecular clouds such as the covering fraction, masses and dynamics
- With this large sample, we will be able to compare the observed distribution of absorbing clouds to predictions from various 3-D accretion models and simulations e.g. Gaspari et al. (2015)



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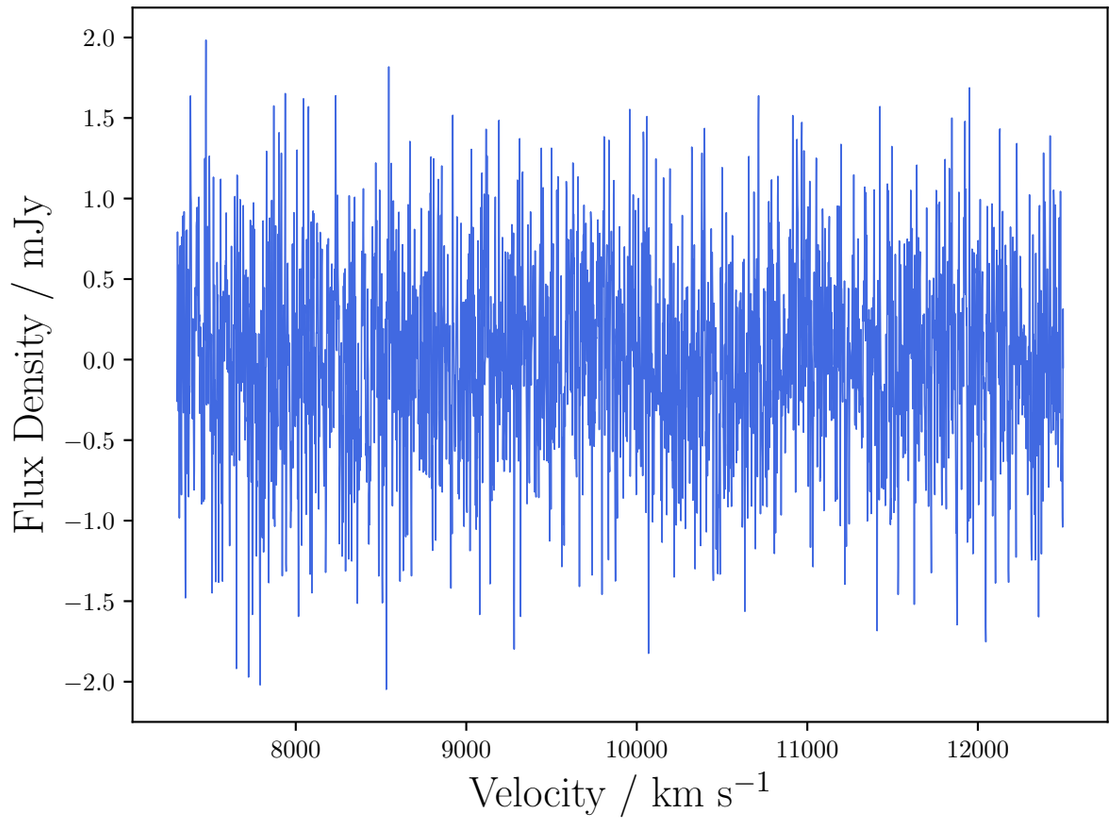

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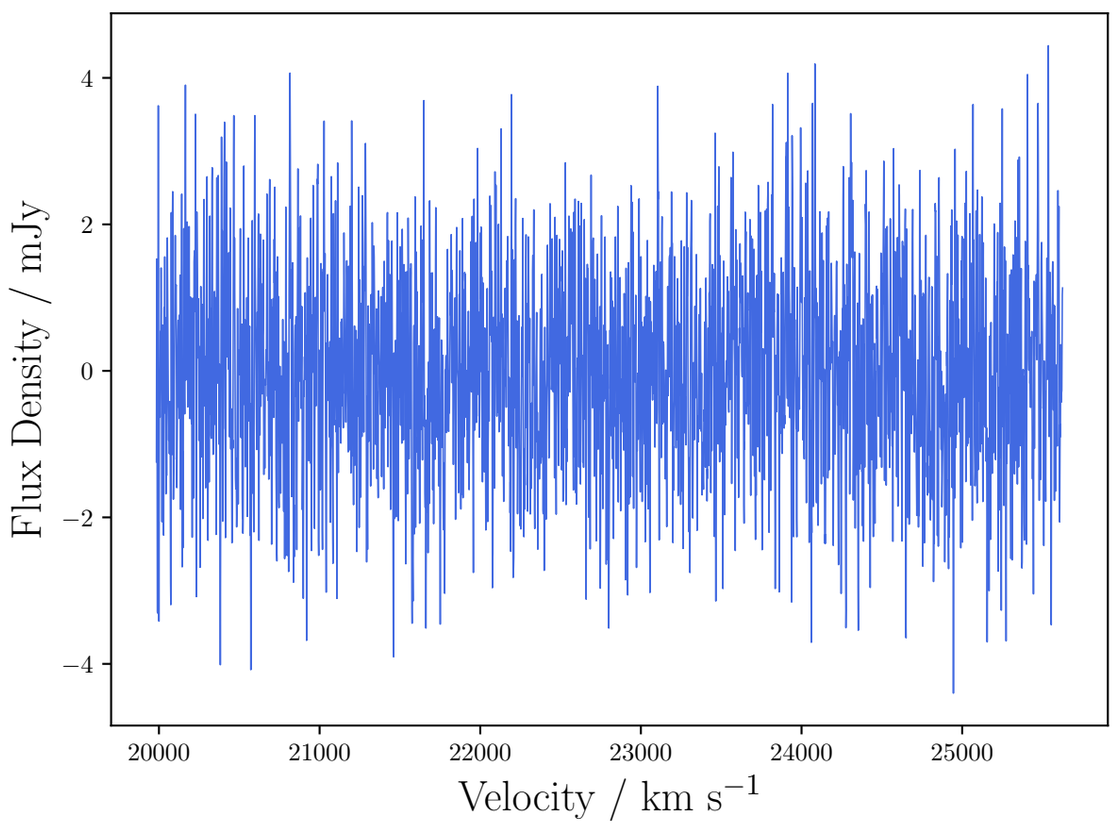

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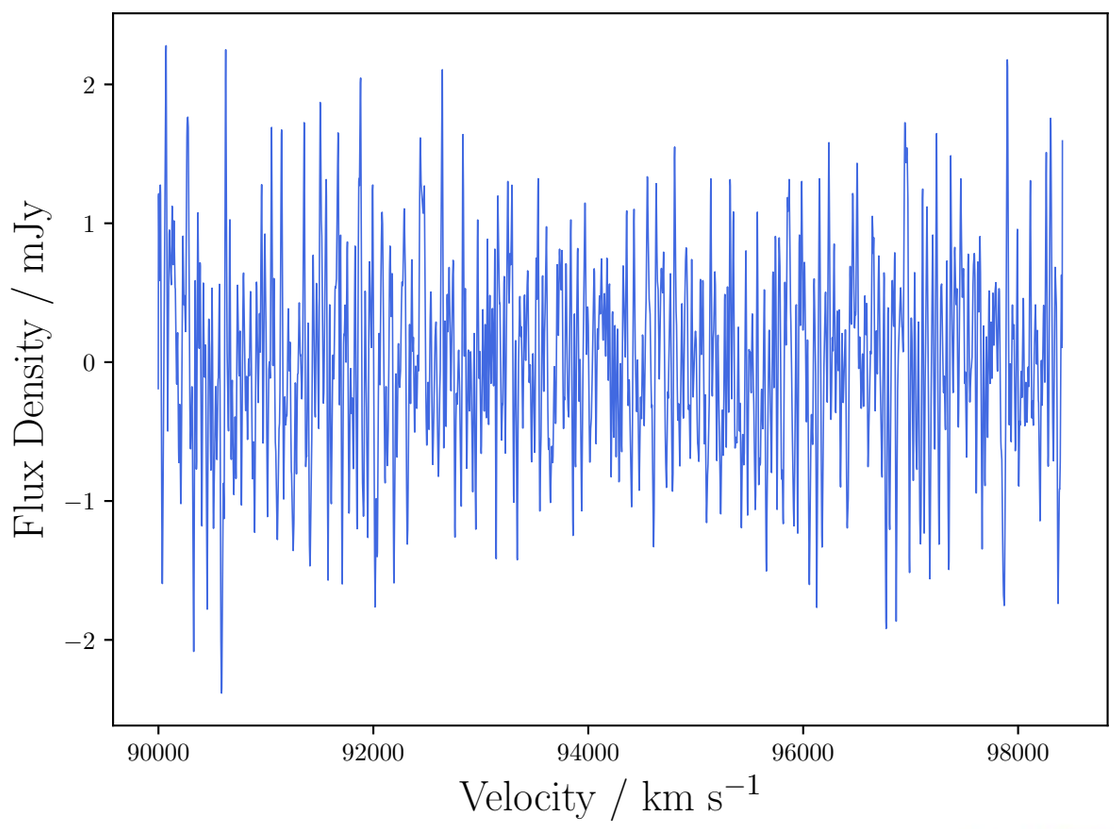

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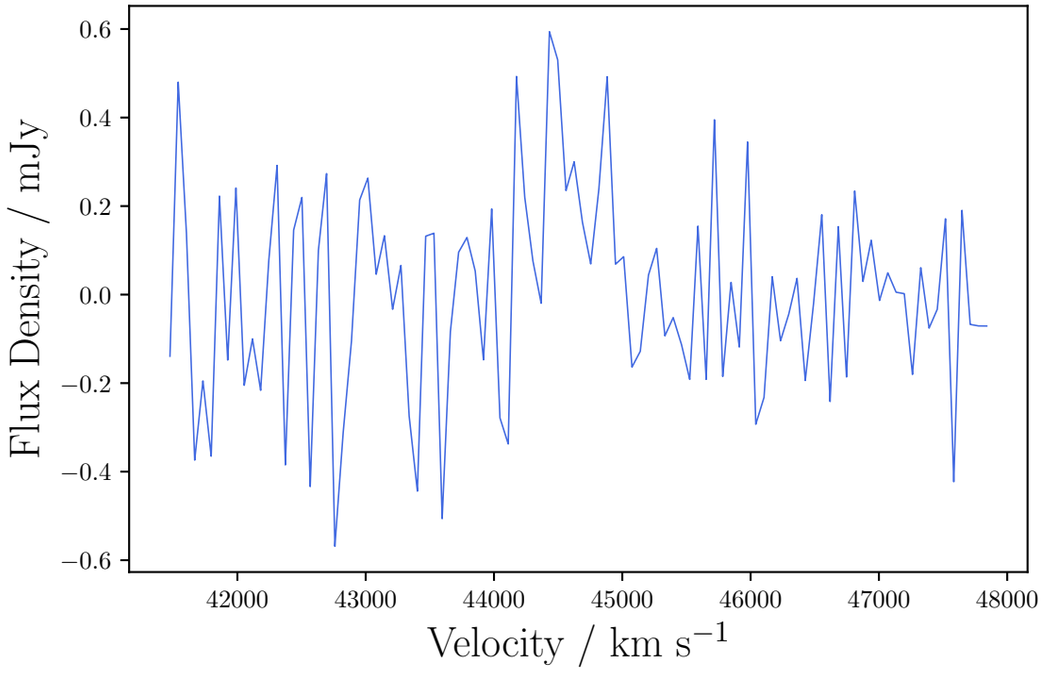

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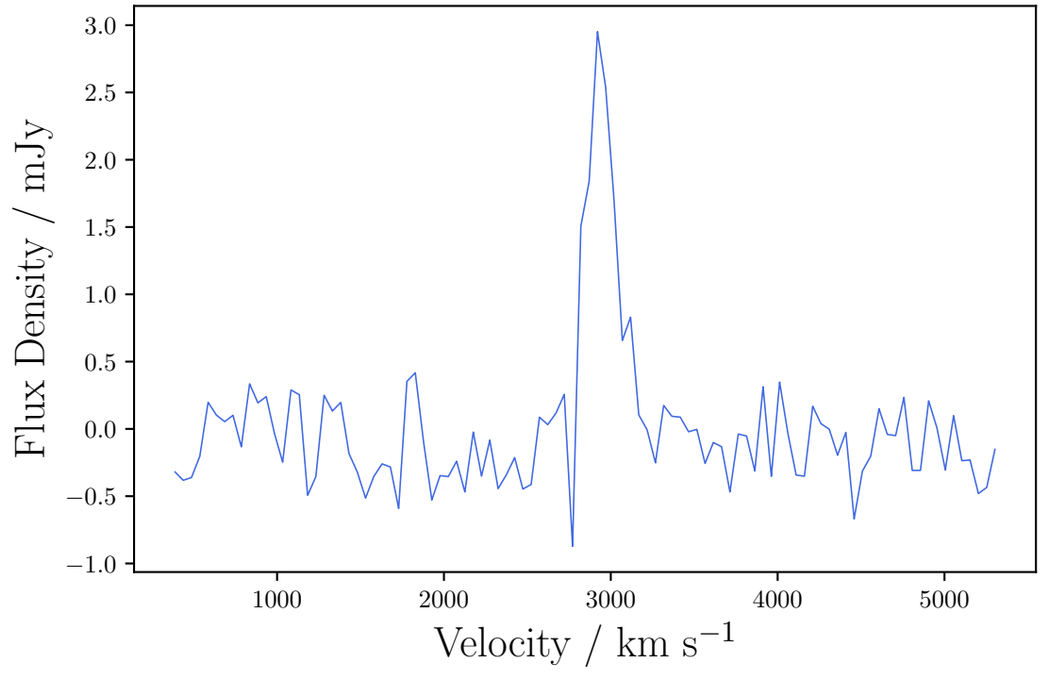
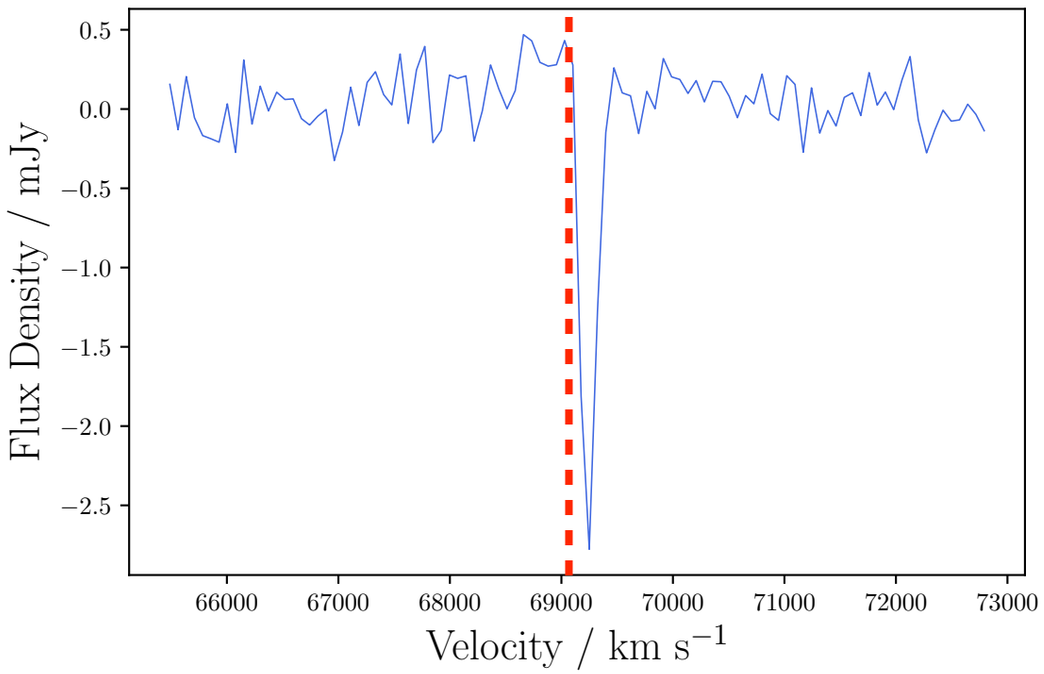


NGC 6868



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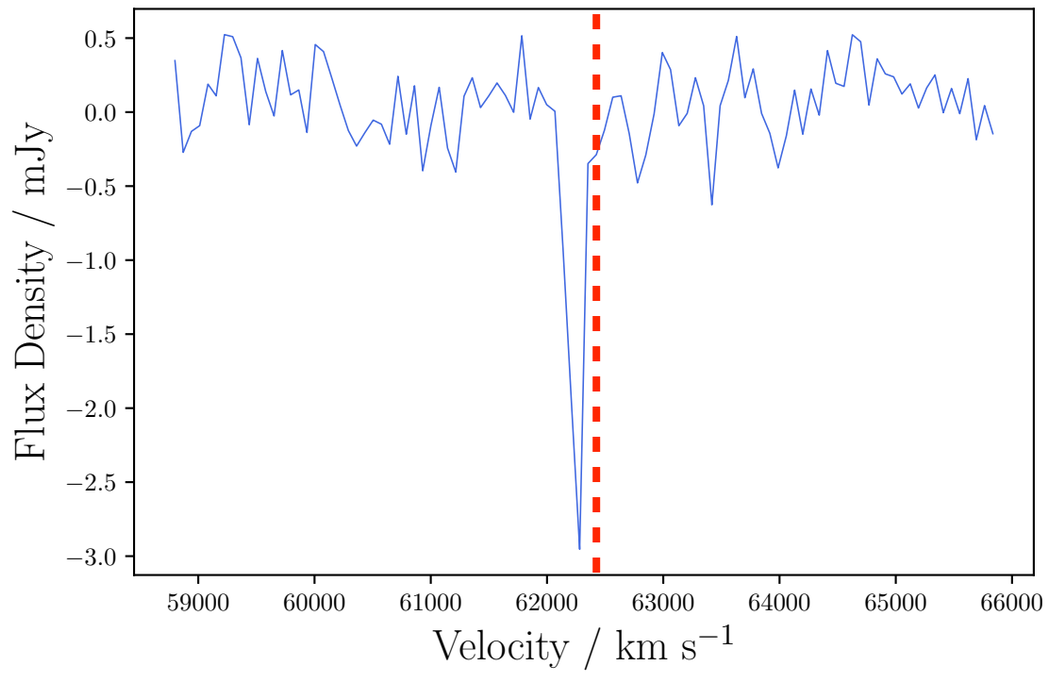

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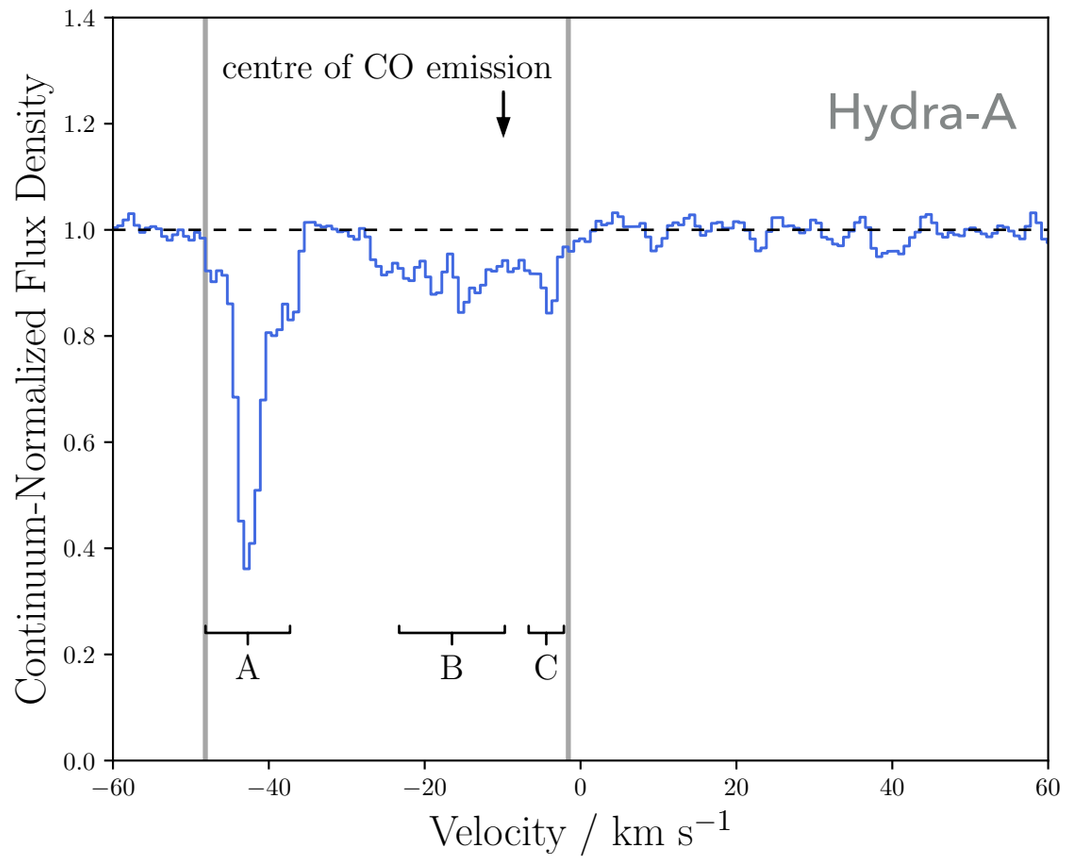
CONCLUSIONS

- ALMA observations of Hydra-A reveal blueshifted groups of molecular clouds along the line of sight to the SMBH
- These have by far the highest optical depths found to date in absorption of this type



- New ALMA CO observations of 24 BCGs with the brightest mm-continuum sources will provide the first definitive constraints on theories of chaotic cold accretion

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